MEBT – Introduction for operators.

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Content:

- MEBT functions and systems
  - Transverse focusing and trajectory correction
  - Longitudinal focusing
  - Chopper
  - Diagnostics
  - Vacuum system

What is MEBT?

MEBT = **M**edium **E**nergy **B**eam **T**ransport line

3.6 meters long 2.5MeV beam transport line between RFQ exit and DTL entrance

MEBT functions:

- Transport beam from RFQ exit to DTL entrance
- Clean residual beam in the gap between minipulses
- Satisfy MEBT/DTL matching conditions

MEBT systems:

- Transverse focusing systems
- Longitudinal focusing system
- Trajectory correction system
- Chopper/antichopper system
- Diagnostics
- Vacuum system

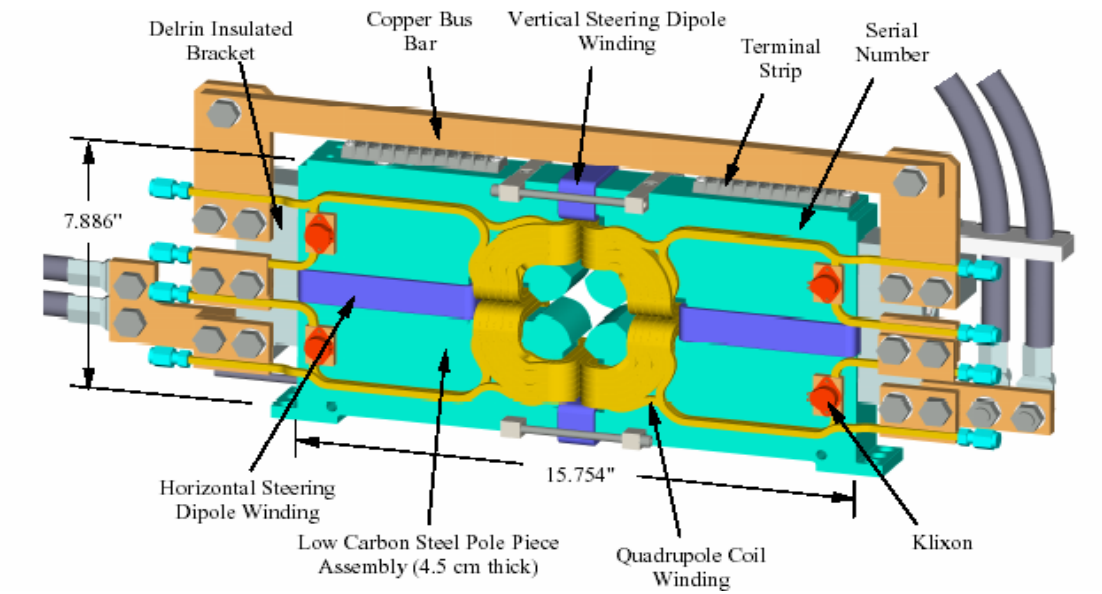
+ subsystems and support systems: cooling, RF, interlocs, etc.

Transverse focusing

Beam passing free through a transport line tends to increase its transverse (vertical and horizontal) size due to angular spread of the ions and due to repulsive forces from the space charge.

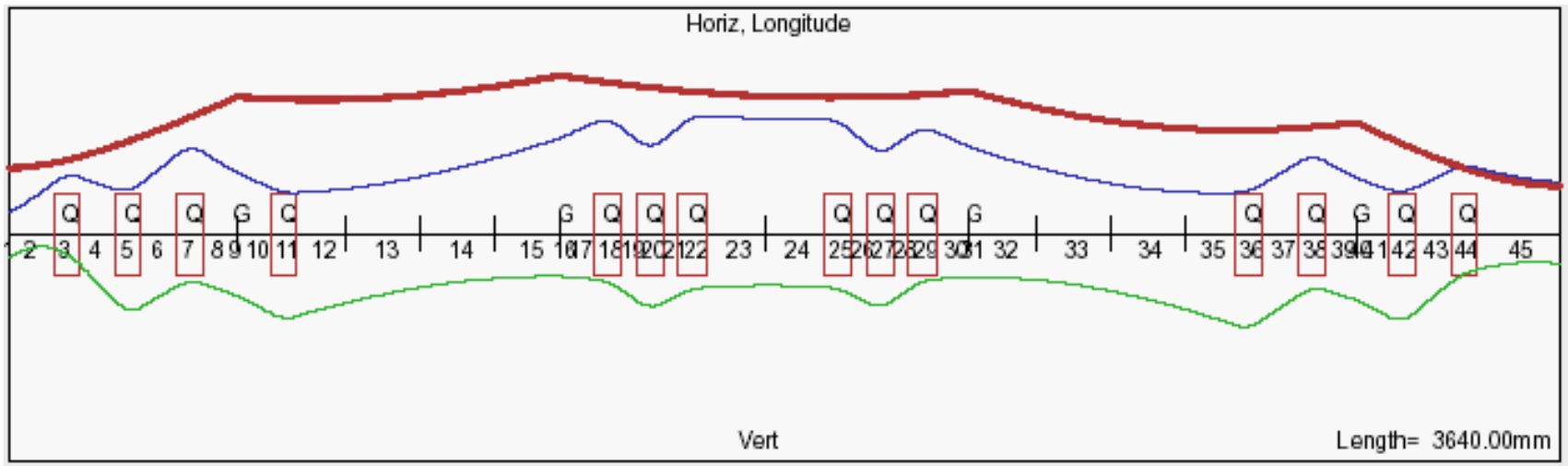
In order to overcome this tendency and keep beam size within vacuum aperture transverse focusing is provided by the MEBT magnetic system consisting of 14 quadrupole magnets:

- 8 quads of 32mm aperture (4 kGs/cm max)
- 6 quads of 42mm aperture (3 kGs/cm max)
- 11 unipolar regulated power supplies
- water cooled coils with temperature controlled interlocs



14 quads are combined in 3 groups by function:

- First four quads are used to transform input beam size and divergence to horizontally flattened shape required to pass between chopper plates. Each of the quads has independent power supply.
- Next six quads are configured as two triplets mirror symmetric about chopper target. Purpose of these quads is to focus the beam on the chopper target properly and provide anti-symmetric transformation from the chopper deflector to anty-chopper deflector. Triplets are powered in series by 3 power supplies.
- Last four quads are used to transform beam size and divergence to the shape required by DTL input conditions. Each of the quads has independent unipolar power supply.



Triplet quads are so close to each other that field overlap reduces integrated strength by ~10%

11 set points for operator: field strength

Trajectory correction

Beam entering the MEBT can be not perfectly centered on the axis. Quadrupole magnets can be not perfectly centered on the axis. As a result beam trajectory can deviate from the straight line.

In order to straighten trajectory six of 14 MEBT quadrupoles have additional windings to produce transverse kick (horizontal and vertical independently).

These windings have independent regulated bipolar power supplies.

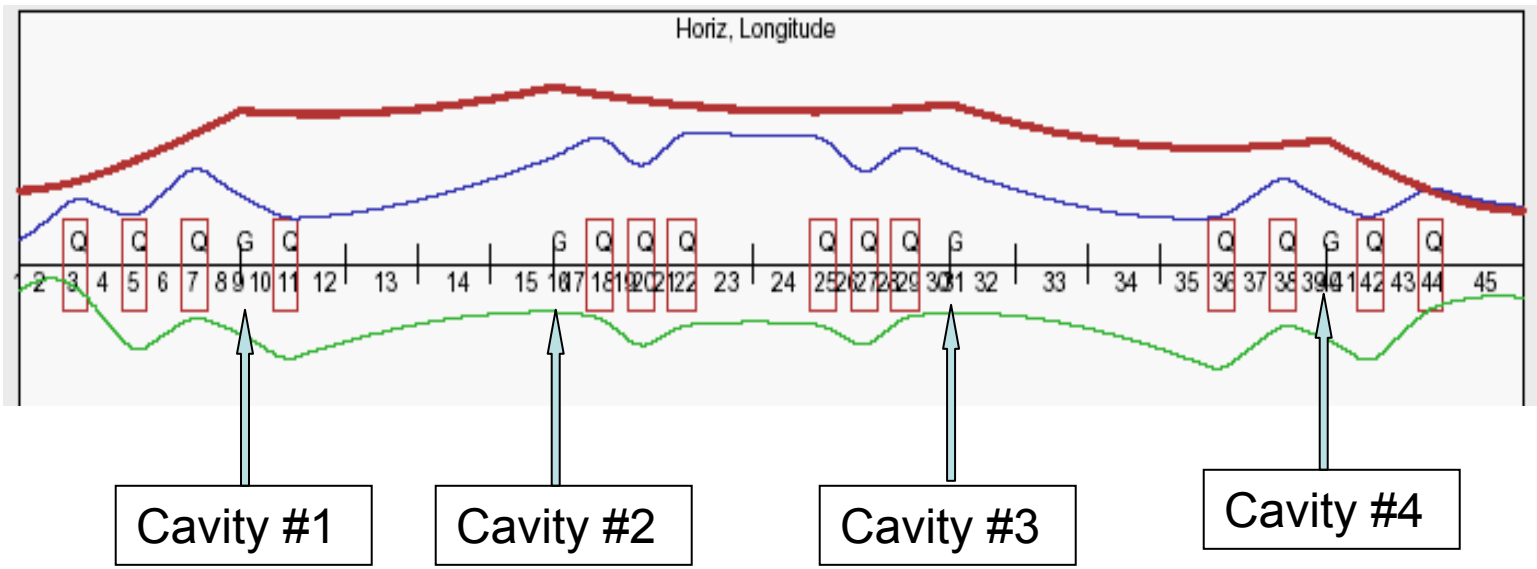
12 set points (6 vertical, 6horizontal): field strength

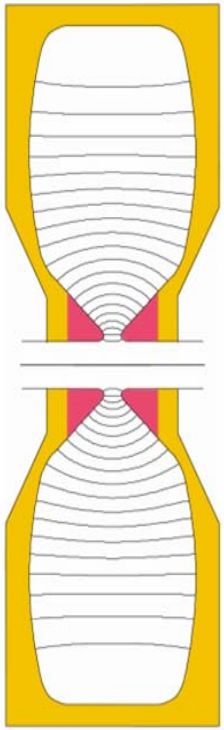
Longitudinal focusing

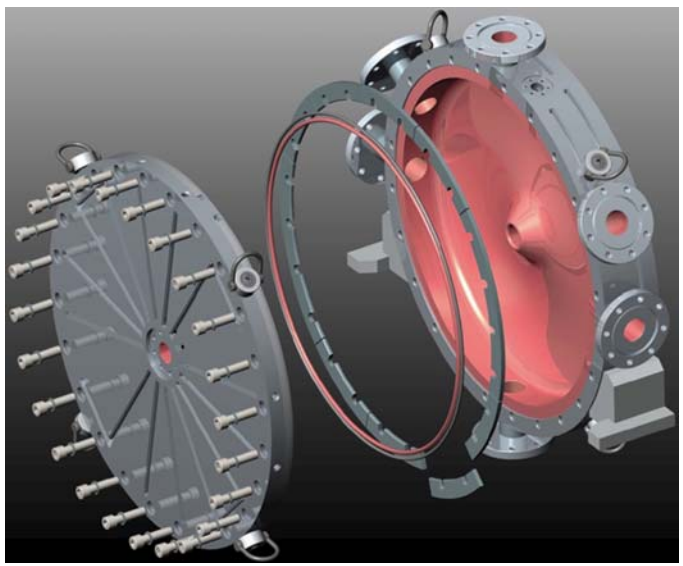
Beam passing free through a transport line tends to increase its longitudinal size (debunch) due to intrinsic velocity spread of the ions and due to repulsive forces from the space charge.

In order to overcome this tendency and keep beam bunched in the MEBT longitudinal focusing is provided by 4 so called ‘rebuncher’ cavities.

Phase of RF voltage in the cavity has to be set to -90⌖ relative to the beam. As a result average energy of the bunch doesn’t change but head and tail receive inward kick providing longitudinal focusing.







Rebuncher cavity parameters:

- Number of rebuncher cavities: 4
- Rebuncher cavity frequency: 402.5 MHz
- Maximum rebuncher peak voltage integral: 90 kV
- Maximum RF power: 20 kW
- Expected max rebuncher cavity rms rms field error: 2%
- Expected max rebuncher cavity rms phase: 1 degree
- Cavity apertures: (1)3.0cm, (2)3.6cm, (3)3.6cm, (4)3.0cm
- Cooling: water

- All 4 cavities have similar design and differ in aperture only. Functionally they are all identical.
- There is a motor driven mechanical tuner to adjust resonant frequency. Resonant frequency, RF power and phase are kept stable by LLRF system.
- The cavities are fed from 4 individual tube RF amplifiers connected to driver loops via high power coaxial cable.
- The cavities are cooled by water.

8 set points (1 phase & 1 voltage for each cavity)

Lossless transport of the beam through the MEBT with all rebunchers cavities switched off is possible but:

- quad settings are different from nominal
- beam is mismatched to DTL in longitudinal phase space

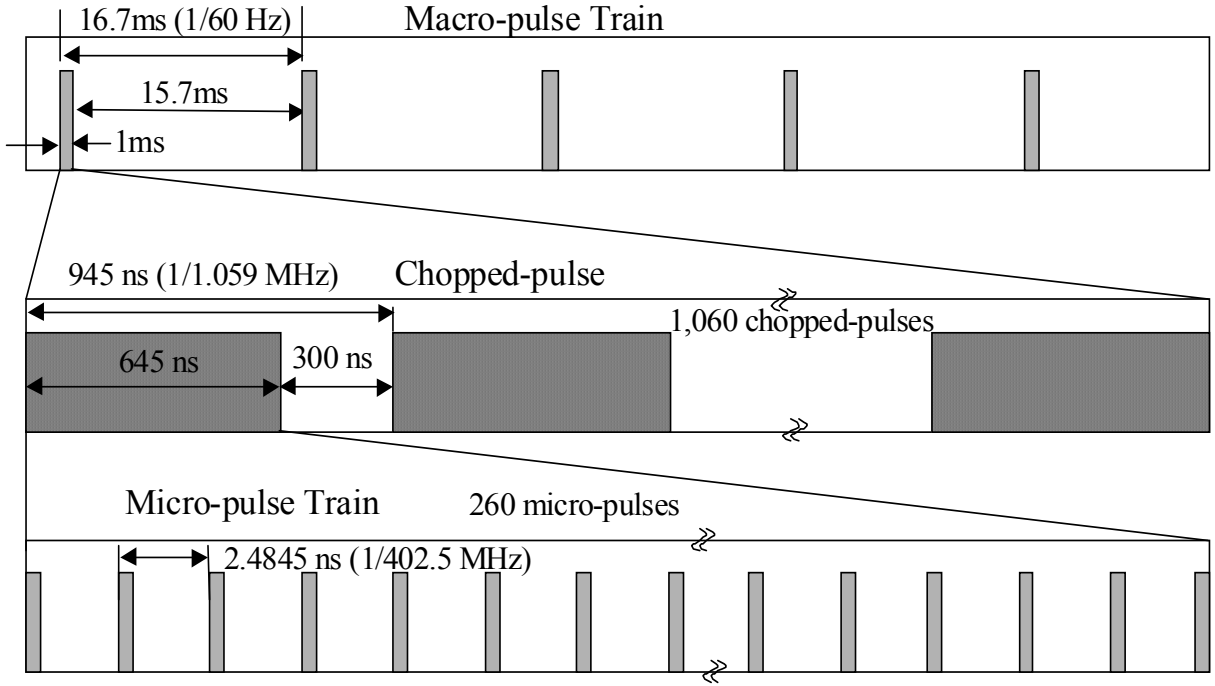
•MEBT Chopper / antichopper system:

Cleans the extraction gap from residual beam left after the LEBT chopper:

reduce Beam In Gap from >10^{-3} to <10^{-4} of nominal current

sharpens gap edges from >20ns to <10ns

SNS beam time structure



Machine pulse

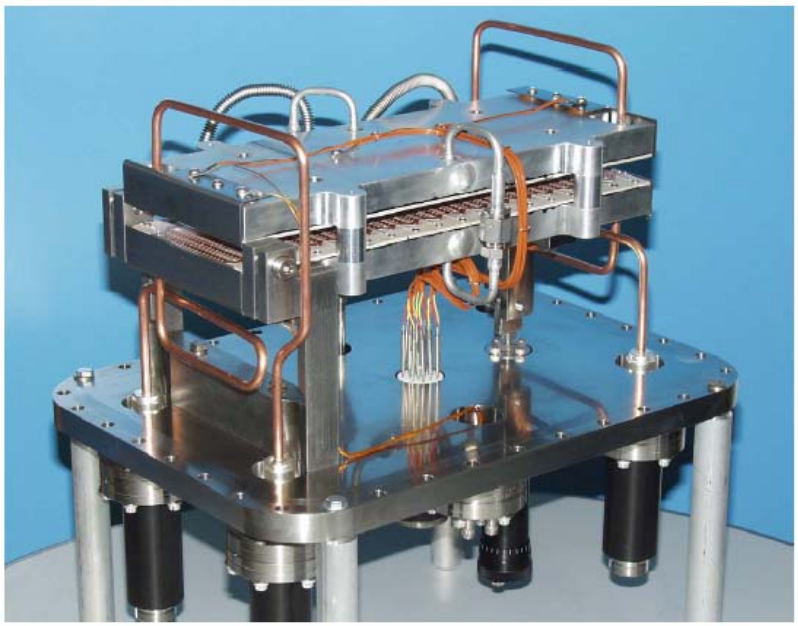
300ns is cut by the LEBT chopper to form gap for extraction from the ring

Bunch train formed by RFQ

MEBT Chopper/antichopper system consists of

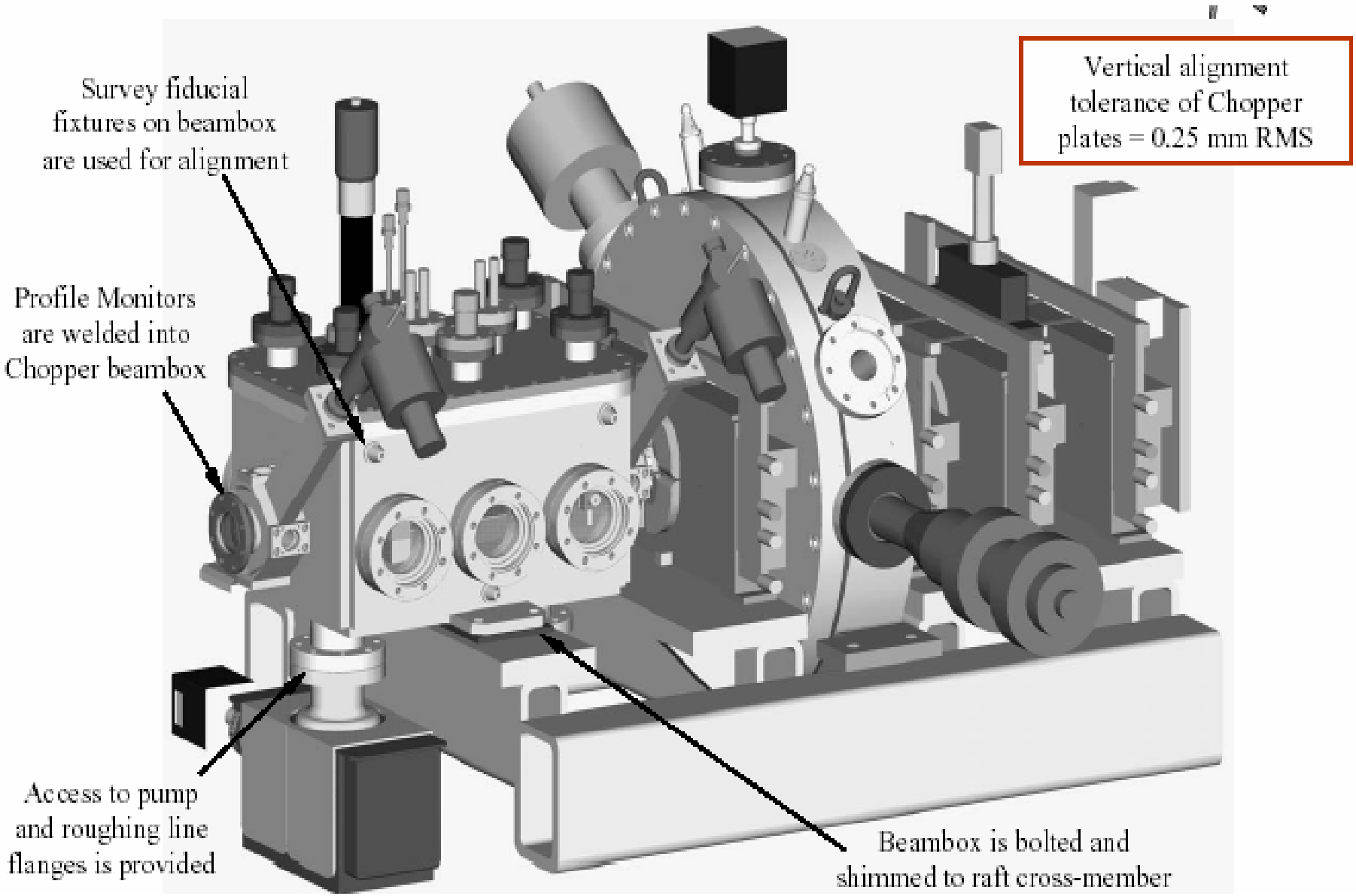
- Fast kicker to deflect beam vertically for gap duration
- target to absorb deflected beam
- Second fast kicker to deflect back on axis particles that missed target
- Pulse generator to provide high voltage pulses

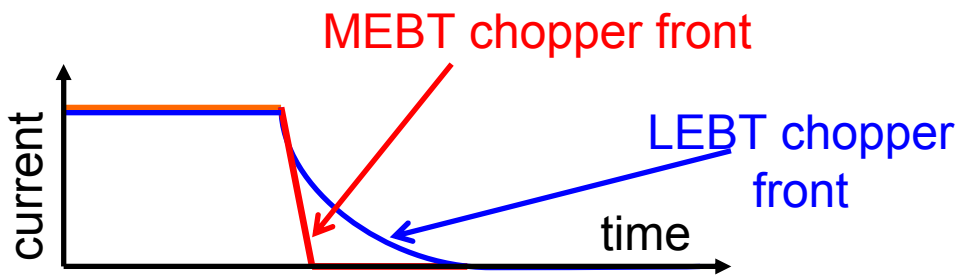
SNS CHOPPER ASSEMBLED TO VACUUM LID



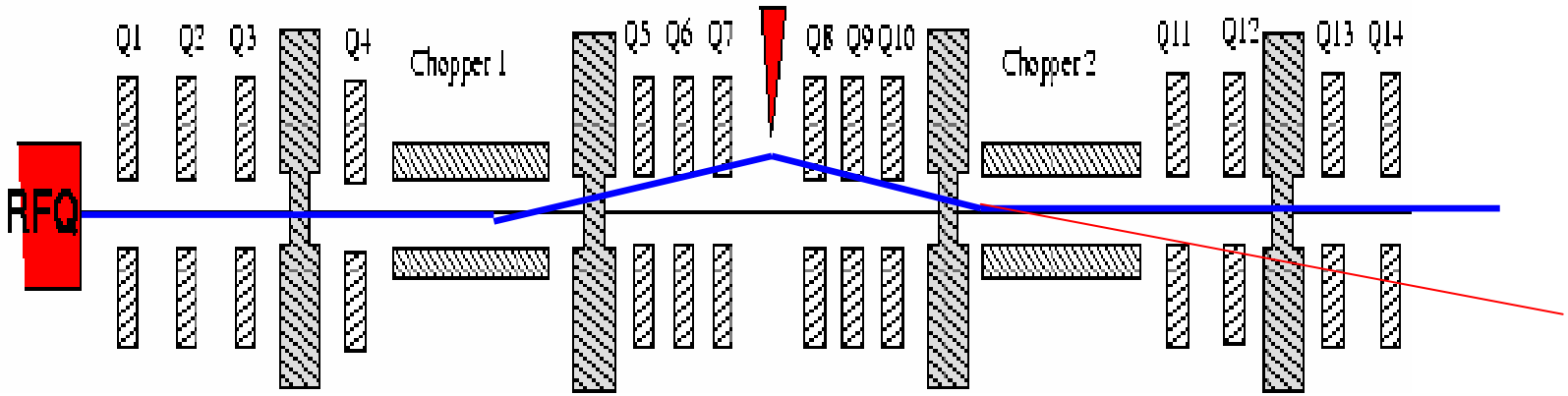
Main parameters:

Length:	35cm
Gap:	18mm
Voltage:	2350V
Rise/fall time:	<10ns
Deflection angle:	18mrad
Max. Target power:	500W


Survey fiducial fixtures on beambox are used for alignment
Profile Monitors are welded into Chopper beambox
Access to pump and roughing line flanges is provided
Beambox is bolted and shimmed to raft cross-member
Vertical alignment tolerance of Chopper plates = 0.25 mm RMS



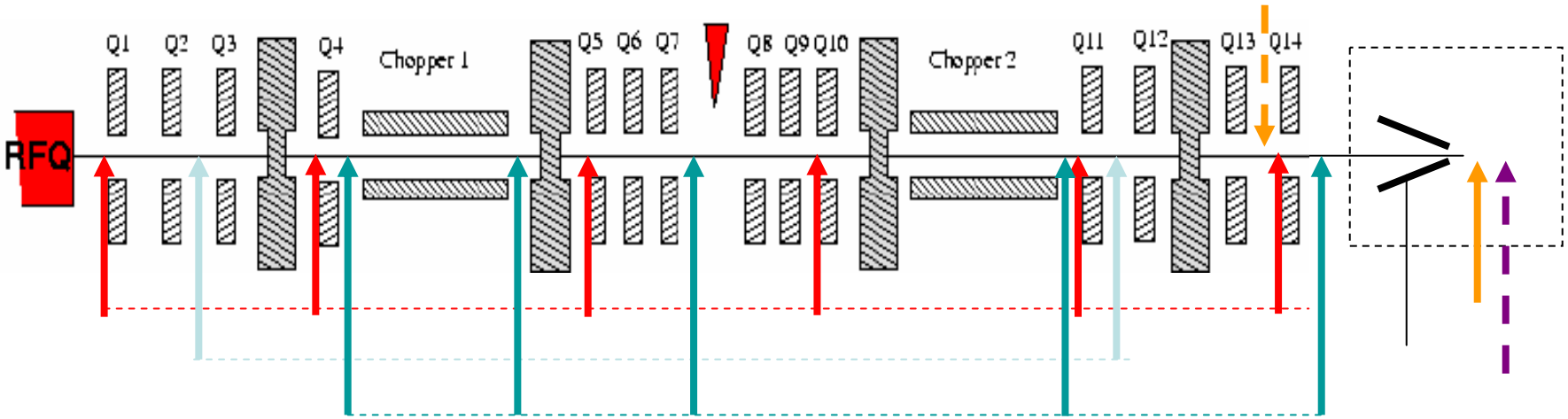
Chopper / antichoper arrangement



Requires proper adjustment of:

- Timing between LEBT chopper, chopper and antichopper
- Focusing between chopper and antichopper (180^{o} phase advance)

MEBT diagnostics



Beam position and phase monitors – 6, vertical and horizontal

Beam current monitors (toroids) – 2

Beam profile monitors (wire scanners) – 5 ,vertical and horizontal

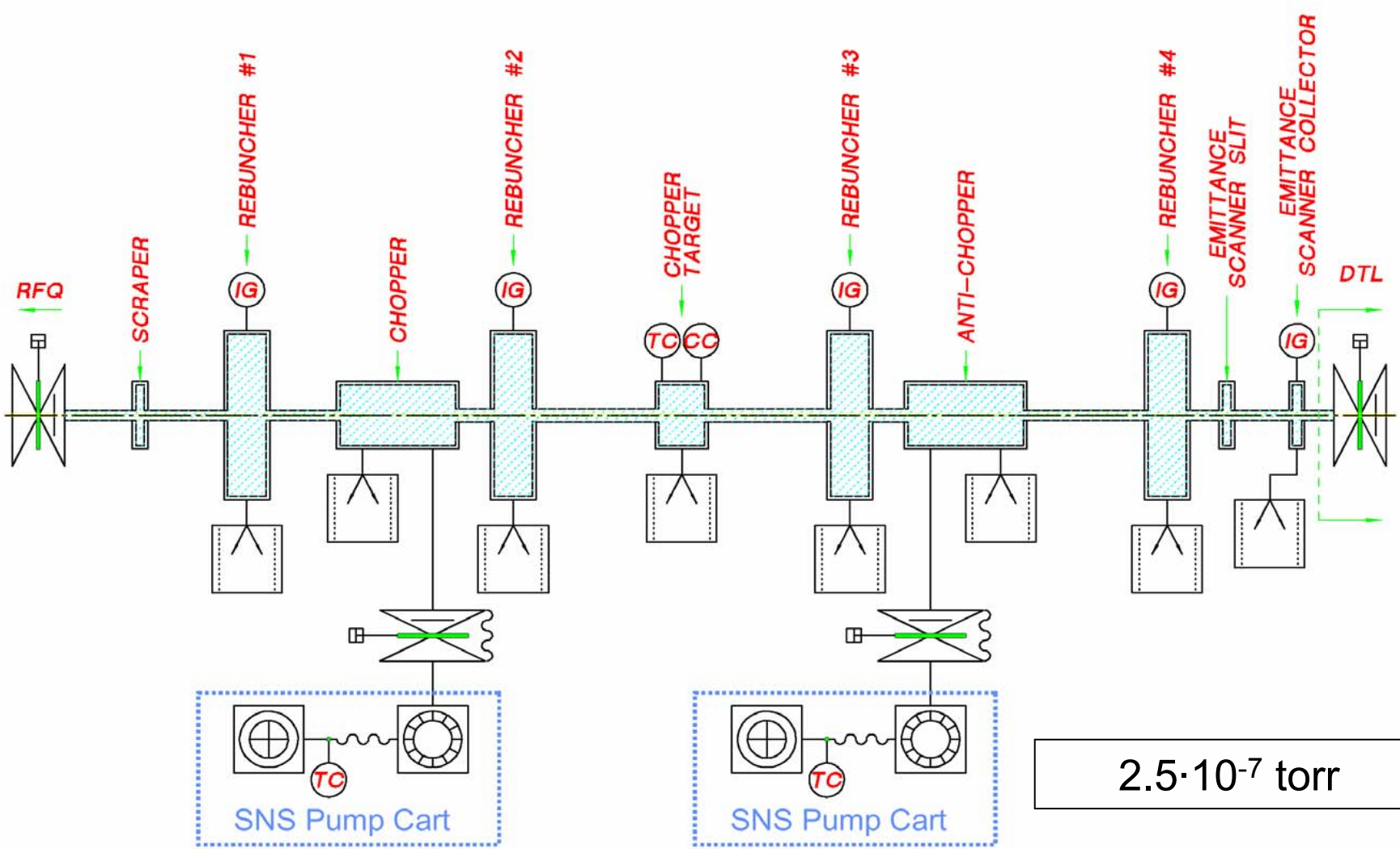
Transverse emittance (slit & collector) - 1 (2)

Bunch longitudinal shape (fast Faraday cup) –(1), R&D

Faraday cup (beam stop)

Laser wire

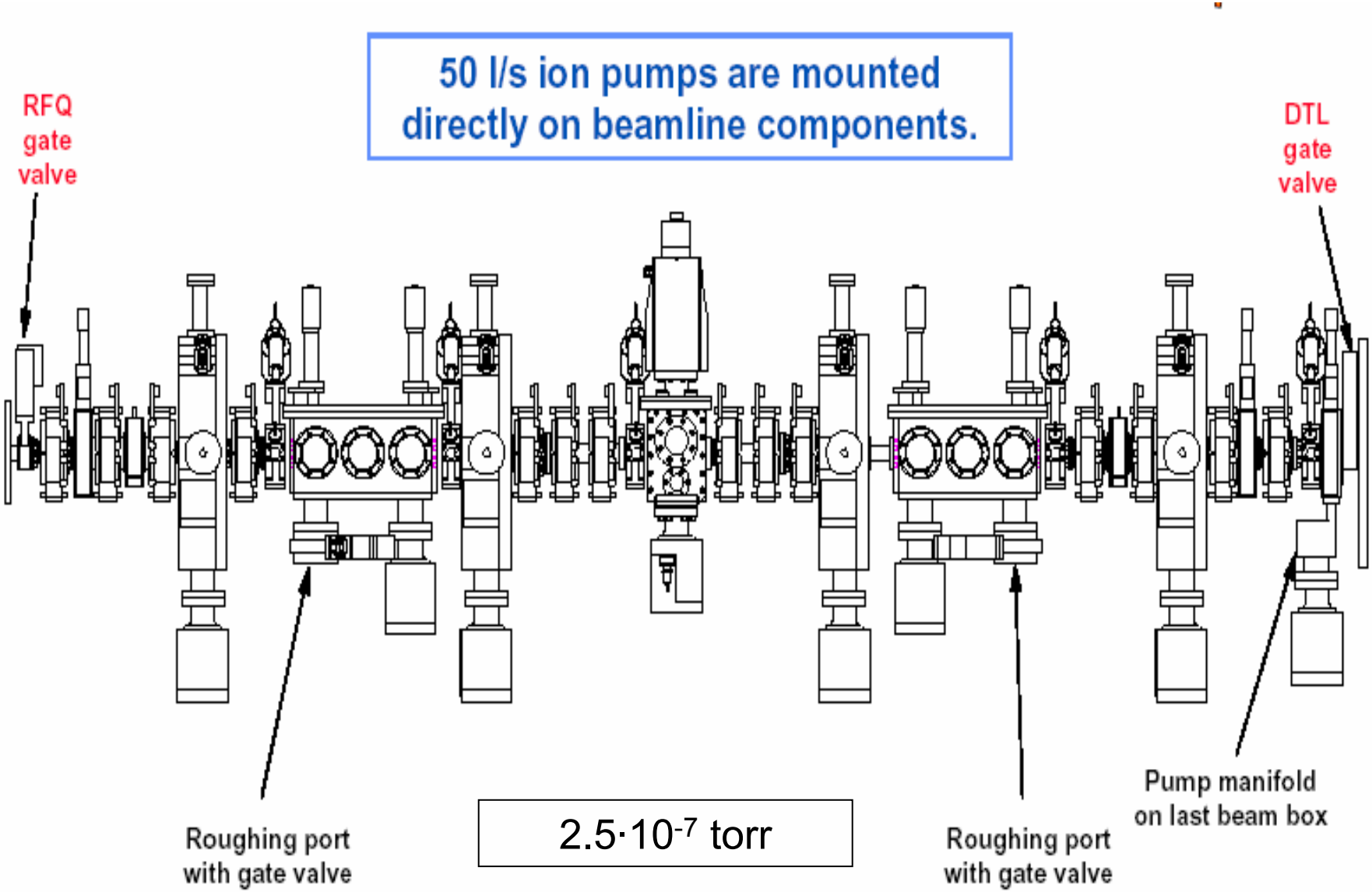
MEBT Vacuum system schematic



$2.5 \cdot 10^{-7}$ torr

Some usefull facts about MEBT diagnostics

- BPMs provide:
  - Beam horizontal and vertical position at BPM location
  - Beam phase at BPM location (relative to reference line)
  - Amplitude of induced voltage: proportional to beam current and function of bunch length
- Beam current monitors provide:
  - Absolute beam current during pulse
  - Charge in the pulse
  - Losses (difference between two BCMs)
- Wire scanners provide:
  - Beam vertical, horizontal and diagonal rms size at wire location
  - Not calibrated for absolute position measurements
- Slit/collector emittance device provides
  - beam footprint in phase space (one plane at a time)
- Faraday cup provides
  - Absolute charge measurements


50 l/s ion pumps are mounted directly on beamline components.
RFQ gate valve
DTL gate valve
Roughing port with gate valve
2.5·10-7 torr
Roughing port with gate valve
Pump manifold on last beam box

MEBT Components